Chapter 14

IMAGING

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INTRODUCTION

The aim of trauma imaging is to identify suspected or unsuspected life-threatening injuries or hemorrhage. This can be achieved with a combination of traditional x-rays, ultrasound, and computed tomography (CT) scanning, as well as the more recently developed magnetic resonance imaging (MRI). Environmental factors that are typical in a military medical environment, such as noise, heat, vibration, and limited space, or patient factors, such as reduced levels of consciousness, often complicate trauma diagnoses. Therefore the trauma team focuses on rapid physical examination closely followed by prompt imaging in order to identify those conditions requiring urgent treatment. The anesthetist's understanding of appropriate radiological modalities for assessment of the patient and how these techniques guide supportive therapy is paramount.

INITIAL TRAUMA ASSESSMENT

Standardized guidelines drive initial patient assessment.[1] Injuries are searched for in a rapid, systematic, and logical way to identify immediate life-threatening conditions before conducting a more detailed secondary survey. Assessment and treatment of the patient often take place concurrently, allowing rapid recognition of a hemodynamically unstable patient who requires urgent surgery. In such cases, no further time should be spent in the resuscitation bay, and the patient should be transferred into the operating theater for surgery. Any immediate life-saving surgical intervention should not be delayed by imaging.

Basic Radiography

All military trauma patients will get a portable chest and pelvic radiograph in the first 5 minutes utilizing digital x-rays that allow immediate review by the clinicians. These plain x-rays provide essential information on possible life-threatening conditions. Chest x-rays are valuable in the diagnosis of a pneumothorax, hemothorax, rib fractures, or a widened mediastinum. Pelvic x-rays can identify pelvic and hip fractures, although the images provide limited information on fracture stability. Pelvic fractures most often occur from a variety of mechanisms that involve high-energy blunt force trauma and have a high morbidity and significant mortality.

Focused Assessment With Sonography for Trauma

Modern ultrasound technology provides a rapid, portable, and reliable method to screen patients with abdominal trauma for the presence of hemoperitoneum. These techniques evolved into a new ultrasound-guided examination method termed "focused assessment with sonography for trauma" (FAST). FAST has been defined by a consensus conference as an expeditious, focused interrogation of the pericardial and peritoneal space looking for free fluid as a marker of injury.[2] All major trauma patients (as defined by an injury severity score [ISS] of greater than 15 or a significant injury to two or more ISS body regions) receive a FAST performed by a consultant radiologist within the first 5 minutes of arrival in the resuscitation room.

FAST is essentially a method of identifying intraperitoneal fluid with ultrasound by scanning several areas: the hepatorenal space, the splenorenal space, and the pelvis. If fluid is detected, it implies a hemoperitoneum requiring urgent surgery, thus negating the need for another confirmatory diagnostic test in an unstable patient. Therefore, FAST can reduce the time from initial assessment to operative care.[3]

FAST can also be used to examine the heart in vivo, which is especially useful in determining the presence of cardiac activity in cardiac arrest, and in the diagnosis of hemopericardium and potential cardiac tamponade.[4] The same ultrasound probe can be used to create a view of the lung bases and diaphragm, once again looking for fluid. Fluid at the lung bases is highly suggestive of a hemothorax, which provides a diagnosis requiring prompt treatment. As knowledge, skill, and technological advances in ultrasound have progressed, the scan can now be used to detect pneumothoraces; this additional component of the scan has been termed "extended FAST" (EFAST).[5]

The FAST scan has superseded the diagnostic peritoneal lavage (DPL) in assessing the presence of hemoperitoneum, and DPL is now rarely used. The combination of plain radiographs and the FAST scan will help direct the insertion of chest drains, pelvic splinting, or emergent thoracotomy/laparotomy, as appropriate. However, if the scan or radiographs are negative, further investigation may be warranted.

Computed Tomography

Computed tomography (CT) scans have been available for several decades, and since the late 1990s whole-body CT has increasingly been used as part of the initial trauma resuscitation.[6] The process has evolved since then, mostly due to advances in CT technology. Now, due to their speed and accuracy in diagnosis, CT scans have not only become an important part of the primary trauma survey, but have also been shown to increase the probability of survival in patients with polytrauma.[7] A whole-body scan from vertex to thighs takes less than 10 minutes, and multidetector row spiral CT (MDCT) allows for scanning large volumes in a single breath-hold. CT scanning of trauma patients provides a high yield of unexpected injuries, in up to 38% of patients in some studies.[8]

Routine and liberal use of CT scans is not without problems. There is always a danger in exposure to ionizing radiation and its associated increase risk of cancer.[9] A second potential issue is cost, although any financial analysis should take into account the costs of missed or delayed diagnosis if CT is not used. Lastly, for the abdominal component of the CT scan, intravenous contrast is required, which raises the possibility of contrast-induced nephropathy and the development of acute renal failure. However, using a CT scanner has become easier in theater due to advances in logistic transportation and readily available technical support.

ANESTHETIC MANAGEMENT FOR IMAGING

The use of CT in a trauma patient requires the anesthetist to prepare for the patient's movement from the resuscitation bay to the scanner. Patients should be hemodynamically stable, have a clear airway or be intubated, be adequately ventilating, and have standard monitors in place. The anesthetic issues related to performing a CT scan are summarized as follows:

- Airway
  - Possibly requires intubation and a rapid sequence induction due to full stomach and a potential difficult airway (unstable spine)
- Monitoring
  - Possibly requires invasive monitoring
  - Careful observation is required for cardio respiratory stability
- Transfer equipment
  - Ventilator and sufficient oxygen cylinder capacity
  - Syringe drivers and drug therapies
  - Suction and emergency drugs
- Transfer
  - Patient is transferred from bed or trolley to scanner
  - Awareness of any spinal injuries is required
- CT scan room
  - Limited access to patient
  - Reduced space
  - Reduced staffing
  - Proximity of resuscitation equipment
  - Patient anxiety
- On-going medical care
  - Continued resuscitation with drug therapies
  - Warmed intravenous fluids

IMAGING BY BODY REGION

In the postresuscitation and postoperative phase of trauma care, imaging remains a useful source of information to track patient progress and guide clinical decision-making. Imaging is a routine part of more formal secondary surveys, and should be used prior to any surgery if the patient remains stable. A variety of modalities are available in the current Role 3 combat support hospital, from the basics of plain films and fluoroscopy to ultrasound and CT. Previously available only in Role 4 facilities, MRI has recently become available at Role 3.[10] MRI can identify a number of injuries not readily visible on CT scan; however, because battlefield trauma frequently has a ballistic component, its use may be limited until further in the timeline, once all metallic risk has been assessed. Nonmainstream radiological techniques have possible applications, which will be discussed after a review of current techniques.

Head Injury

CT is the mainstay of imaging for craniocerebral trauma. Any suspected head injury requires CT assessment to identify hemorrhage, mass affect, and edema; CT scans can also be used to accurately and quickly insert minimally invasive intraventricular drains.[11] MDCT, if available, can transform CT scans from a cross sectional view to full 3-dimensional views, allowing greater yield for maxillofacial pathology.

Imaging is critical to both the diagnosis and management of traumatic brain injury (TBI). For diagnosis of TBI in the acute setting, noncontrast CT is the modality of choice because it quickly and accurately identifies intracranial hemorrhage that warrants neurosurgical evacuation. For the management of TBI patients, noncontrast CT readily identifies the progression of hemorrhage and signs of secondary injury relevant to neurocritical care, such as cerebral swelling, herniation, and hydrocephalus.

Historically, skull plain films have had a place in mild head trauma, identifying fractures, air-fluid levels, and foreign objects. However, intracerebral injury can occur without any of the listed pathology. Therefore, plain films are used less frequently if the mechanism of injury suggests possible craniocerebral pathology, and a full CT scan should be performed if available. The deteriorating patient on the ward, after initial assessment, should also receive a CT because the decline in neurological state would be highly suggestive of an intracerebral cause.

Thoracic Injuries

The plain chest radiograph is a simple and common modality in the diagnosis of thoracic injuries and can provide good information about the thoracic organs and surrounding structures and tissues. On admission to the intensive care unit, the patient routinely receives a chest radiograph, allowing identification of the correct positioning of lines, chest drains, and endotracheal tube. A chest radiograph gives good diagnostic information about the lung fields and can reveal some pathognomic signs for other cardiac complications, such as tamponade or pericardial effusion.

Pneumothorax and hemothorax are readily identified on a plain film, if of sufficient size, but a poor quality film, complicated by supine positioning of the patient, alters the dependent areas and can lead to diagnostic uncertainty, requiring CT for clarification. Lateral supine films can increase yield for recognition of intrapleural fluid and pneumothoraces, but with the availability of CT these are rarely performed. Ultrasound by a skilled operator can be used to identify a pneumothorax, pleural fluid depth, and degree of loculation, as well as to guide drain placement. Differential diagnosis between fluid and blood is difficult with ultrasound and if necessary a CT scan can be used to distinguish between the two.

Lung soft tissue injuries, such as blast lung or pulmonary contusion, are often imperceptible on initial assessment and may only be suggested by a decline in respiratory gas exchange. Plain film changes can often take several hours to develop, whereas CT findings are seen much earlier. It is well accepted that the initial radiological signs of pulmonary contusions often fail to show the extent of the lesion. CT pulmonary angiography also has its place in the diagnosis of pulmonary embolism; however, careful consideration should be given to the impact of contrast medium on the patient and to whether such an investigation would change current management.

Cardiac Injury

Hemodynamic instability in the post–acute-phase trauma patient could point to cardiac compromise if other causes such as hypovolemia and tension pneumothorax have been excluded. Plain chest films are unhelpful, except in excluding these other causes, but echocardiography, either transthoracic or transesophageal is far more useful, allowing diagnosis of pneumopericardium, pericardial effusion and tamponade, together with their effects on cardiac function. Echocardiogram-guided pericardiocentesis also improves safety and success rate. CT scans will show gross anatomy, along with evidence of a pericardial effusion, pneumopericardium, or pneumomediastium, but will not allow assessment of cardiac performance.

Vascular Injury

Blunt aortic injury is considered the second most common cause of death after head injury in blunt trauma patients. If an aortic injury does not cause death immediately, the patient may present with severe hemodynamic instability or even be totally asymptomatic. Accurate and rapid diagnosis is vital. Plain chest films can reveal some signs, such as widened mediastinum, depression of left mainstem bronchus, or lateral displacement of the trachea. However, in one study, nearly half of patients identified with aortic rupture by CT had a normal mediastinum on plain film, and only 12% of patients with a widened mediastinum had an aortic injury.[12] An aortogram has been the gold standard for imaging in suspected thoracic trauma, but it is invasive and time consuming, and does not detect small intimal injuries that are seen on CT or transesophageal echocardiography. One study has shown CT to have a sensitivity of 99%, as compared to 92% in angiography for blunt aortic injury.[13] Angiography has largely been replaced by CT and is now reserved for difficult to diagnose cases.

A newer evolution in using CT to assess peripheral vascular damage in limb injuries is a carefully timed bolus of contrast followed by rapid acquisition of data (10 seconds or less) over long vascular territories.[14] This can be done relatively safely by releasing the tourniquet for this short period of time.

Intraabdominal and Pelvic Injury

CT is the mainstay of radiological assessment for trauma-related intraabdominal and pelvic injury. Damage to any viscus as well as evidence of ischemia can be identified, guiding decisions on further surgical intervention.

Musculoskeletal Injury

Imaging for musculoskeletal injuries is very much the remit of orthopedic surgeons, who require radiography for diagnosis and guiding management. Initial diagnosis of injuries will be with the full body CT and plain film on first trauma assessment. Any further directed imaging such as plain films would be on the advice of the orthopedic team.

ULTRASOUND REGIONAL ANESTHESIA AND VENOUS ACCESS

Ultrasound is routinely used in the combat hospital for regional techniques including nerve blockade and the placement of nerve block catheters. Difficult vascular access can also be aided by ultrasound images, and should be used when possible for gaining central venous access in accordance with guidance from the National Institute of Clinical Excellence.[15].

Interventional Radiology

Because of the patterns of injury in the current conflict, interventional radiology such as embolization of bleeding from pelvic trauma is not used. Interventional radiology does have some application in the civilian world, but will not be discussed here. However, inferior vena cava filters (IVCFs) have been used in combat trauma patients, and have been subject to lengthy discussion. Recent developments in damage control resuscitation, using massive transfusion protocols and early use of recombinant factor VII, render major trauma patients at risk of prothrombotic complications when pharmacological thromboprophylaxis is not appropriate. Use of IVCFs decreases the risk of complications such as pulmonary embolism without the problems associated with pharmacological prophylaxis. However, the lack of prospective randomized trials in this area has created a void in evidence-based recommendations. Retrievable IVCFs, which can be removed at a later date when the risks of venous thromboembolism have decreased,[16] may offer the best risk-benefit ratio for traumatized patients (although they are likely to be used only at Role 4).

FUTURE DIRECTIONS IN IMAGING

An increasing body of published literature is documenting further developments in FAST, including its use in assessing cardiac function as a transthoracic echocardiogram, viewing the inferior vena cava diameter to assess volume status and degree of hypovolemia, and viewing the optic nerve sheath diameter, which can act as an indicator of raised intracranial pressure.

Using data from CT scanning for research could provide further insight into patterns and mechanisms of blast injury, in particular the altered metabolism and hemodynamics in TBI.

New portable technologies for the battlefield may include transcranial Doppler to monitor intracerebral hemodynamics. This technology is readily available and is used in many intensive care units, including military hospitals, to monitor patients for vasospasm. Portable devices for monitoring pupillometry are similarly employed in intensive care units and may prove useful in the battlefield. Similarly, near-infrared optical imaging devices are under development that could measure oxygen extraction ratios with 5- to 15-mm resolution and up to 10 mm deep under the skull. A key issue raised by these emerging technologies is balancing research needs, which might guide new therapies and help prevent injury to soldiers, with the existing burdens of gear weight and the need for medical personnel in the field to focus on delivering life-saving care and moving personnel out of harm's way as quickly as possible.[17]

SUMMARY

An essential part of the initial trauma assessment, imaging comprises plain radiographs, FAST scans, and CT scans. Further imaging may be required after the initial trauma assessment, usually in the modality of a plain film or CT. Ultrasound has many uses apart from FAST, including facilitating vascular access and the provision of regional anesthesia.

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